Response to MAC 2014 recommendations

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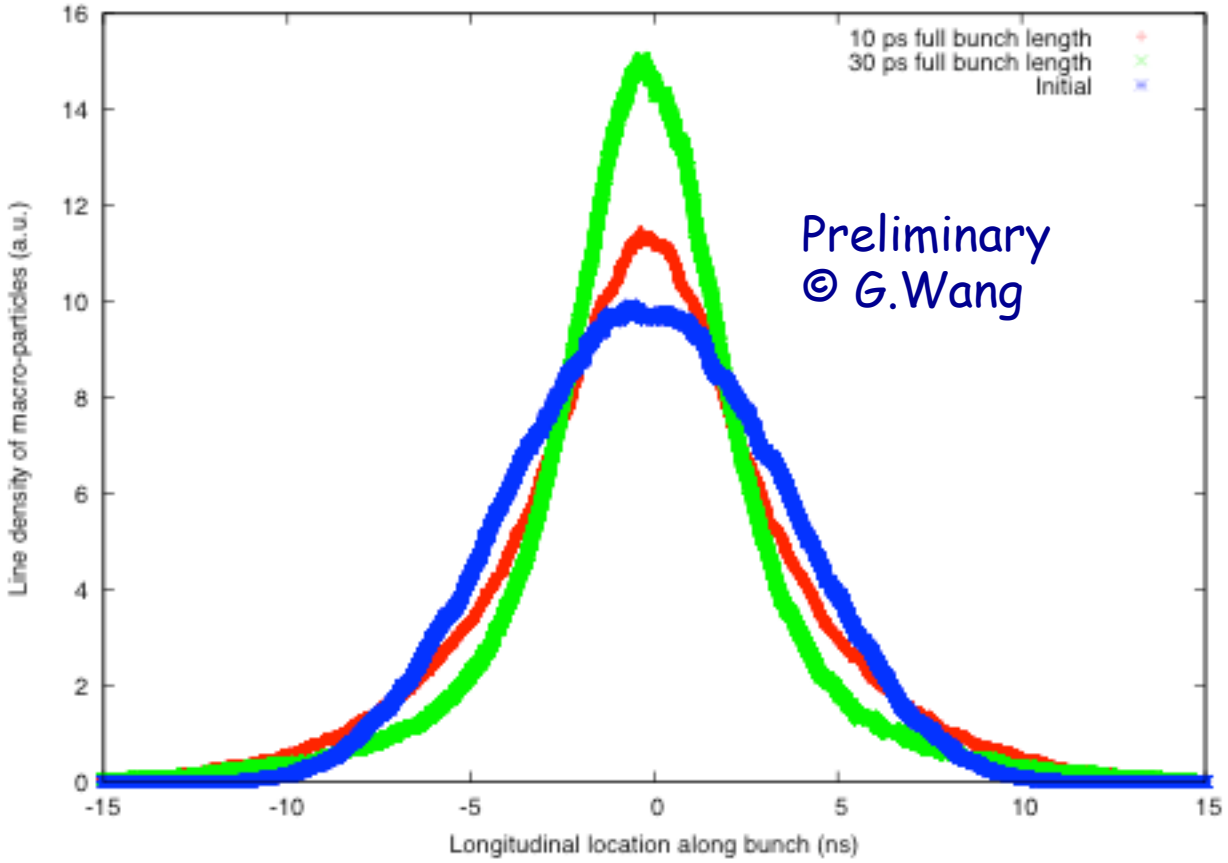
Recommendations

- Carry out an overall review of the (somewhat complicated) theoretical design of the presently envisioned CeC-PoP test with the help of external FEL experts to make sure it will work as planned and that nothing has been left out.
  - There was too many external and internal reviews and retreats to fit this one into already very busy schedule. CeC theory and simulations were one of the topics reviewed by eRHIC R&D advisory committee in August 2014. We plan to have a dedicated review of the CeC theory in 2016.
- Continue to carry out modeling studies of the cooling process with realistic ion bunch parameters in the time domain, including the IBS
  - We continued modeling of the processes with more realistic beam parameters including developing new computational tools - all in house. Unfortunately reduced (by 50%) level of funding did not allow to continue simulation efforts at Tech X.
- Carry out cooling simulations with non-Gaussian electron bunches as seen and expected from the SRF gun
  - Unfortunately reduced (by 50%) level of funding did not allow to continue these simulation efforts at Tech X at full scale. Tech X made some progress, but we would need about $100K of additional funds to make predictions for realistic beams. It will be combined with our own program to simulate the evolution of the ion bunch in presence of the CeC.
- Determine the observables for the initial set of experiments. Define a minimum set of observations to declare success.
  - We defined the observables and minimum set of observations: (a) local cooling ; (b) longitudinal cooling of the entire bunch with intensity reduced to 1/6 of nominal
- Initiate planning
  - We developed detailed plan and resource-loaded schedule.

Cooling full bunch
Self-consistent simulations



Plot shows evolution of Au ion bunch profile after 40 mins of CeC using 1 nC (10 psec long) and 3 nC (30 psec long) electron bunches.

Schedule

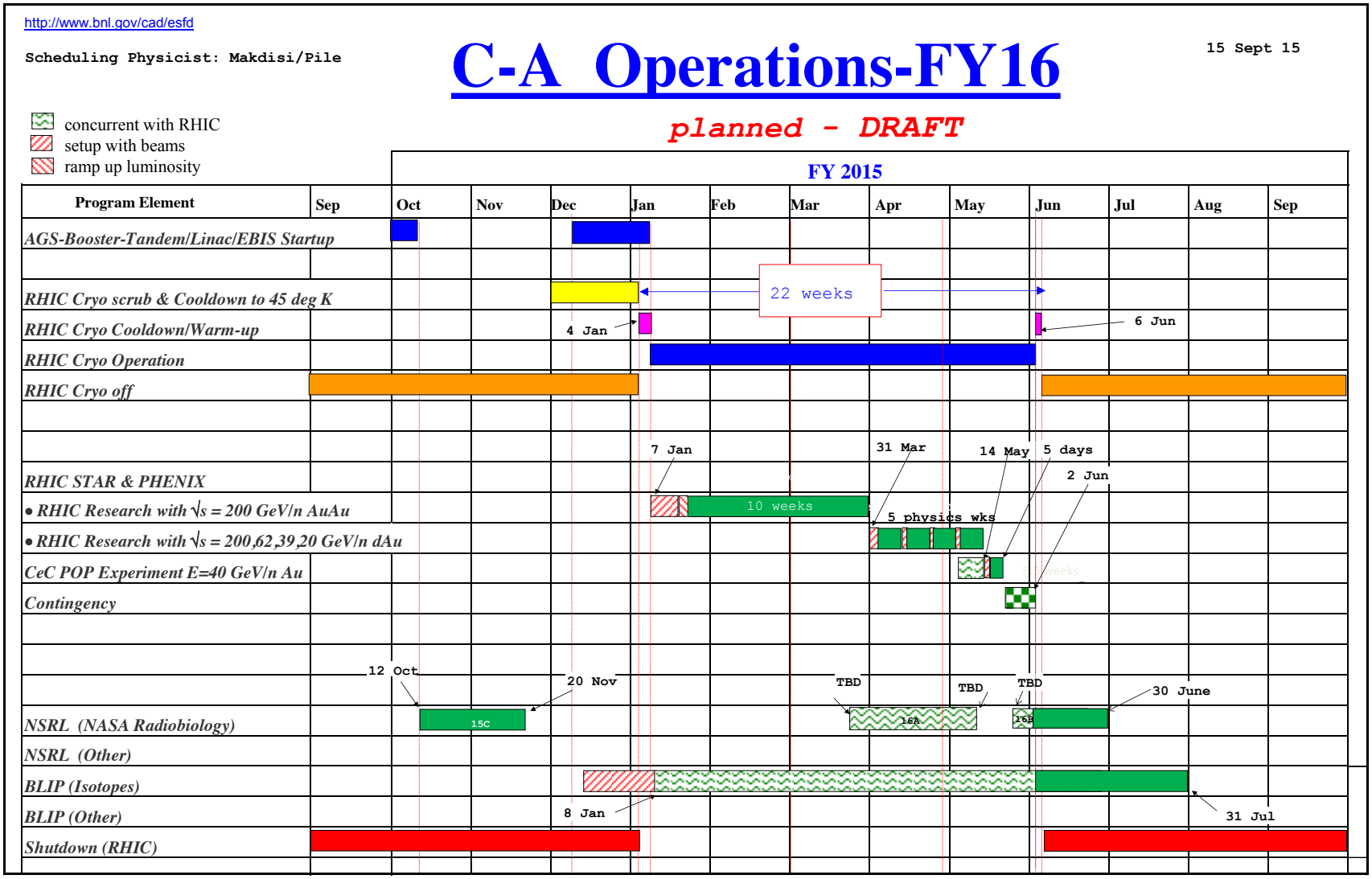
Construction

CeC PoP experiment is a DOE NP competitive R&D project –
we are submitting quarterly progress and budget reports

x - a milestone, X – major milestone

Delivery of 704 MHz linac to BNL	✓	30-Jul-15
Assembling and tuning helical wigglers	2/3 done	1-Oct-15
Installing/plumbing the 704 MHz in RHIC tunnel	x	15-Nov-15
Install helical wigglers in RHIC tunnel	x	01-Dec-15
CW laser is commissioned	x	01-Dec-15
Beam diagnostics is intalled		15-Dec-15
Optical diagnostics is installed		15-Dec-15
Complete CeC beam-line	**X**	**15-Dec-15**

CeC experiment is now a part of RHIC Run-16 plan



Schedule for RHIC run 16

(dates are tentative and are adjusted to the preliminary RHIC Run 16schedule)

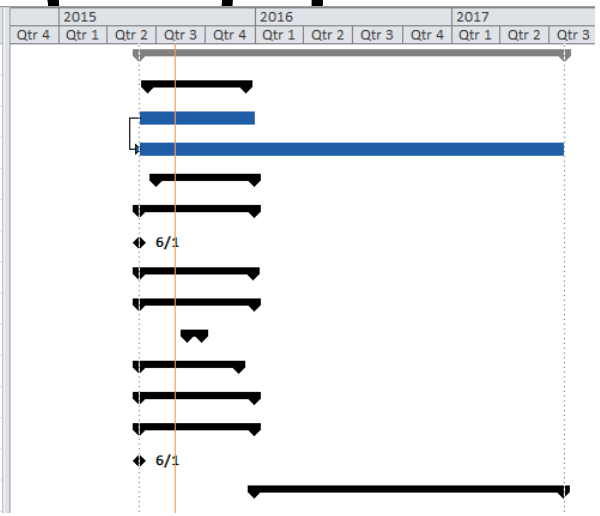
Commissioning	Milestones	End date	
SRF cavities cold	x	15-Jan-16	Has to be synchronized with RHIC run
Complete cavity conditioning	**X**	**20-Feb-16**	
Generating first beam	**X**	**10-Mar-16**	
Measuring beam parameters	X	1-Apr-16	
Propagate beam to the beam dump	x	20-April-16	
Test co-propagation with ion beam	**X**	**1-May-16**	
Demonstrate FEL amplification	**X**	**15-May-16**	
First cooling attempt	**X**	**02-Jun-16**	Dedicated 5 days of running

Schedule - demonstration

(dates are tentative and will be adjusted to RHIC Run 17)

Making necessary up-grades/ improvements	01-Jul-16	31-Dec-16	Improving and updating diagnostics, optical system, as well as installing buncher for ACeC test
SRF cavities cold	x	15-Feb-17	Has to be synchronized with RHIC run
Complete cavity conditioning	**X**	**01-Mar-17**	
Recreating operational conditions	**X**	**21-Mar-17**	
Start CeC PoP experiments (using APEX shifts)	**X**	**07-Apr-17**	
Demonstrate microbunching amplification (ACeC)	x	30-May-17	if time allows
Demonstrate CeC PoP cooling	**X**	**30-Jun-17**	
CeC cooling experiments end	**X**	**30-Jun-17**	Dates have to be adjusted to the end of the RHIC run

WBS	Task Name	% Complete	Work	Cost	Start	Finish
1.	Coherent Electron Cooling (CeC) Experiment	10%	41,938 hrs	$8,511,691	6/1/2015	7/28/2017
1.1	Milestones	0%	0 hrs	$0	6/15/2015	12/15/2015
1.2	Project Management	0%	2,260 hrs	$408,068	6/1/2015	12/31/2015
1.3	Physics Support	0%	21,824 hrs	$3,173,125	6/1/2015	7/28/2017
1.4	SCRF Electron Gun	0%	0 hrs	$0	7/1/2015	12/30/2015
1.5	SCRF Linac Cavity	8%	264 hrs	$590,322	6/1/2015	12/31/2015
1.6	Buncher Cavity	100%	0 hrs	$0	6/1/2015	6/1/2015
1.7	Magnets + Power Supplies	10%	4,506 hrs	$745,317	6/1/2015	12/28/2015
1.8	Instrumentation Gassner	28%	1,216 hrs	$551,478	6/1/2015	12/31/2015
1.9	Beam Dump	0%	56 hrs	$9,369	8/28/2015	9/23/2015
1.10	Vacuum	0%	1,058 hrs	$519,500	6/1/2015	11/30/2015
1.11	Cryogenics	0%	2,076 hrs	$326,730	6/1/2015	12/31/2015
1.12	Controls Jamikowski	0%	934 hrs	$224,058	6/1/2015	12/31/2015
1.13	Civil Construction	100%	0 hrs	$0	6/1/2015	6/1/2015
1.14	Commissioning	0%	7,744 hrs	$1,963,724	12/31/2015	7/26/2017



Resource Name	Work	Cost
Building Trades-Riggers	42 hrs	$6,466
Building Trades-Carpenters	**84 hrs**	**$12,932**
Building Trades-Electricians	**472 hrs**	**$72,664**
Central Shops	**498 hrs**	**$76,667**
Designer	500 hrs	$77,355
IT Professional	880 hrs	$150,841
Admin	880 hrs	$155,619
purchases < $25K	178,414	$276,542
Grad Student	**10,560 hrs**	**$316,800**
Engineer	**2,189 hrs**	**$435,545**
Technician	**6,771 hrs**	**$1,047,541**
purchases > $25k	893,000	$1,062,670
Scientist	**19,008 hrs**	**$4,820,049**

Project Name	CeC Experiment
Total FTEs	**23.8**
Unburdened Material Cost (k$)	**$1,071**

CeC Photo-injector

- Adopt a robust cathode material with sufficient quantum efficiency
  - We use CsK_2Sb in our SRF gun and generated up 1.7 MeV beam with 3 nC per bunch charge
  - We built a “garage” to keep three cathodes, which can be inserted into the gun within one hour
  - Second garage is used for fresh cathode deposition and can replace the other in 2 weeks.

CeC: Overview of Construction Progress, Final Installation Planning

- With respect to the available resources, the installation and commissioning of components for CeC PoP may be in competition with the set-up of the LEReC experiment. In order to avoid delays, an early prioritization should be made by the management for the case of conflicts
  - We developed detailed plan and resource-loaded schedule, which is compatible with LEReC.

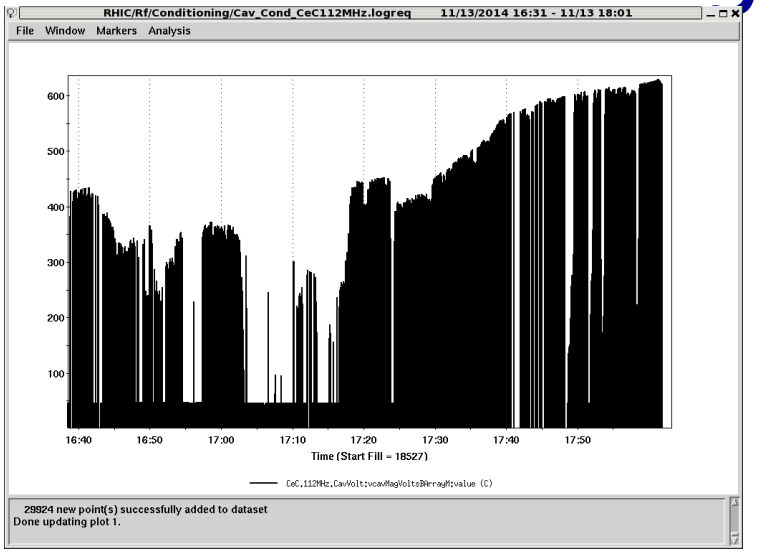
CeC: Theory/Simulations

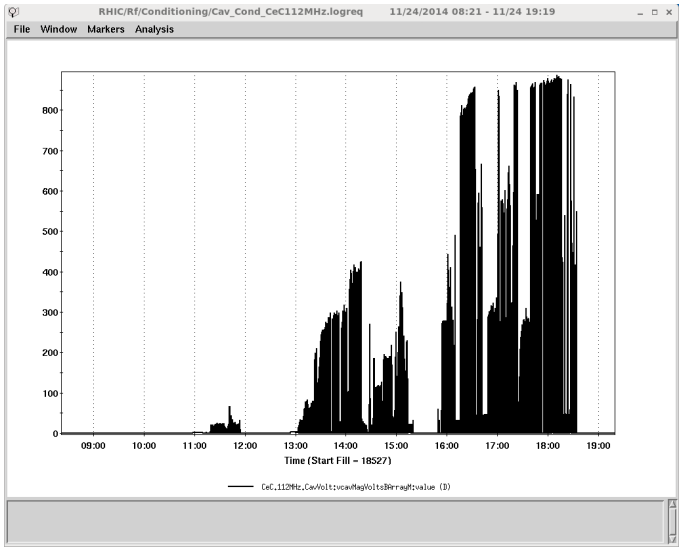
- Update the simulations of predicted cooling and diffusion in the Proof-of-Principle test and clarify the relation to experimental observables
  - We started the simulation, with a home-grown code, of the evolution of the ion bunches in CeC PoP including diffusion from IBS and CeC. It will be used to further define the expected observables.
- Since the CeC-PoP will not test all aspects of the full CeC, specify clearly which essential physics and hardware aspects of CeC will be tested and which not
  - CeC PoP will test all aspects of longitudinal cooling, including saturation and diffusion. What would not be tested is coupling of this cooling to transverse direction. Demonstrating the later would require both significant financial resources and significant RHIC modifications. Coupling (re-distribution) of longitudinal and transverse damping is a standard technique in electron/ position storage rings. It used for redistribution of damping between longitudinal and transverse (horizontal) directions. Using the coupling of horizontal and vertical directions was successfully demonstrated in RHIC when a single plane stochastic cooler was cooling both horizontal and vertical oscillations.
  - Hence, we are considering demonstration of coupling and redistributing CeC cooling as an established technique and as a lower priority than demonstrating t novel and untested CeC

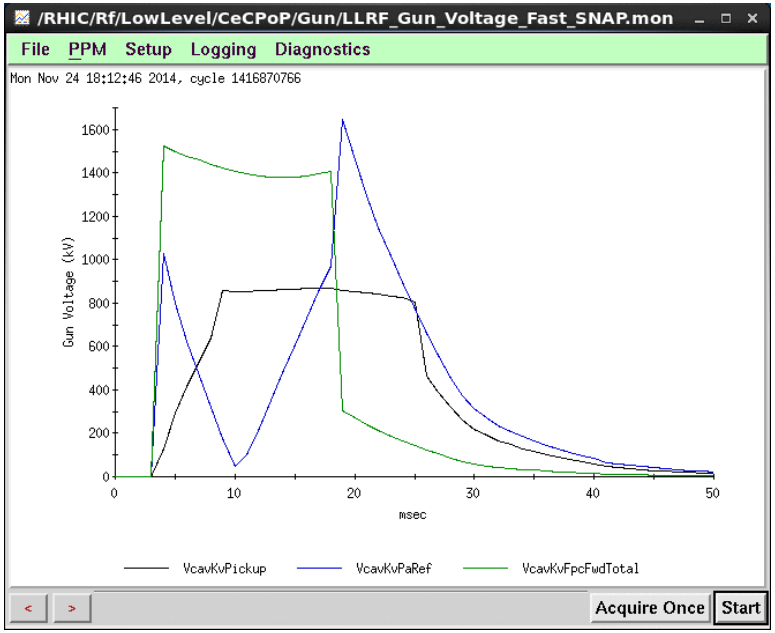
CeC: SRF and Warm RF Components

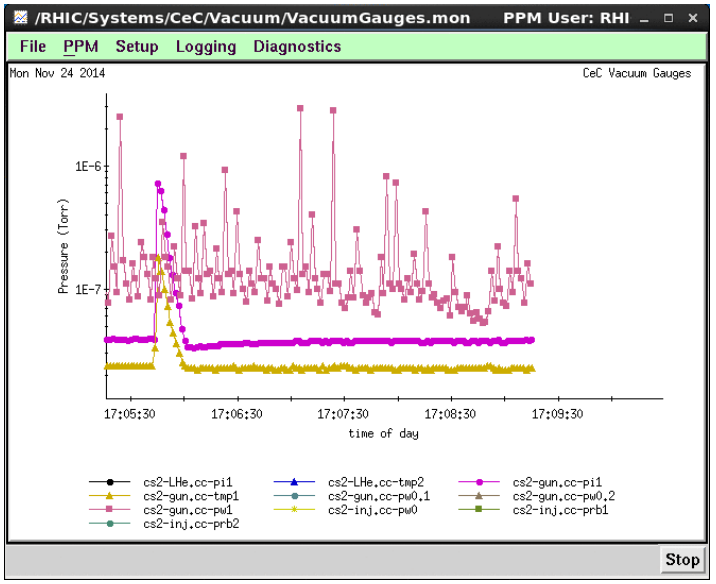
- Push forward the commissioning of the SRF gun, monitor and report the progress.
  - We were very successful and in a last-ditch effort demonstrated operation of CeC SRF gun with CsK2Sb photocathode.

Conditioning 112 MHz Cavity





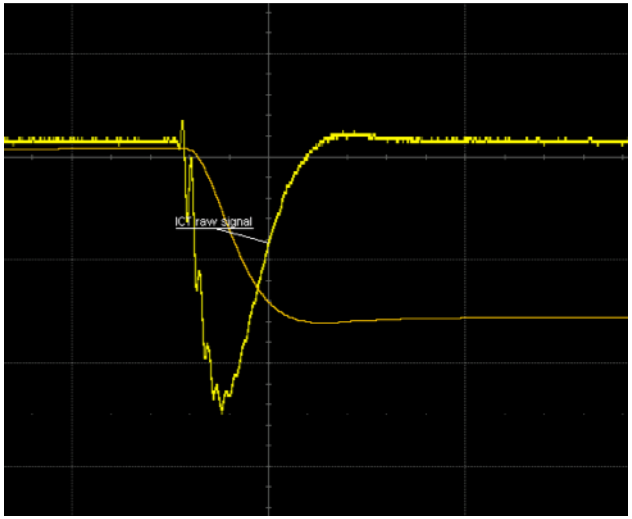


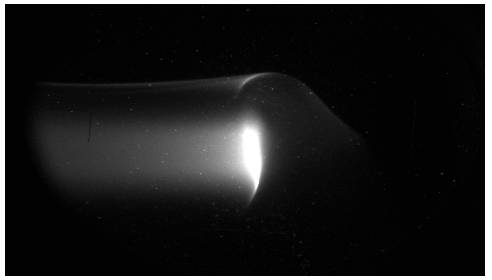


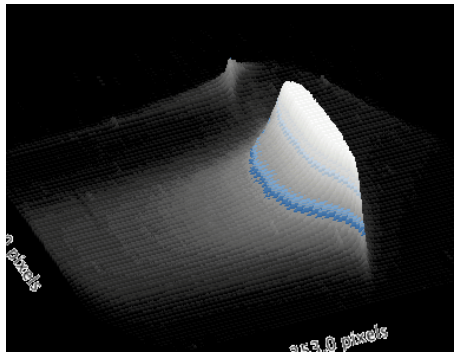
Coherent electron *Cooling* PoP

First beam from 112 MHz gun – June 2015

- 1.6-1.7 MeV (kinetic energy) in CW mode
- Laser generated CW e-Beam with 3 nC @ 5 kHz
- 2 MeV in pulse mode
- 25 MV/m at photocathode







Milestones reported to DoE NP Q3 FY15

Demonstrating operation of 112 MHz SRF gun with 3 nC charge per bunch, 1.6 to 1.7 MeV kinetic energy in CW mode and above 2 MeV in pulsed mode.
Production of high QE photocathodes for 112 MHz SRF gun.
Receiving helical wiggler system for CeC PoP FEL amplifier
Completion of the 704 MHz SRF linac cryo-module at NioWave Inc.
Completing the low energy transport beam line and its control system.

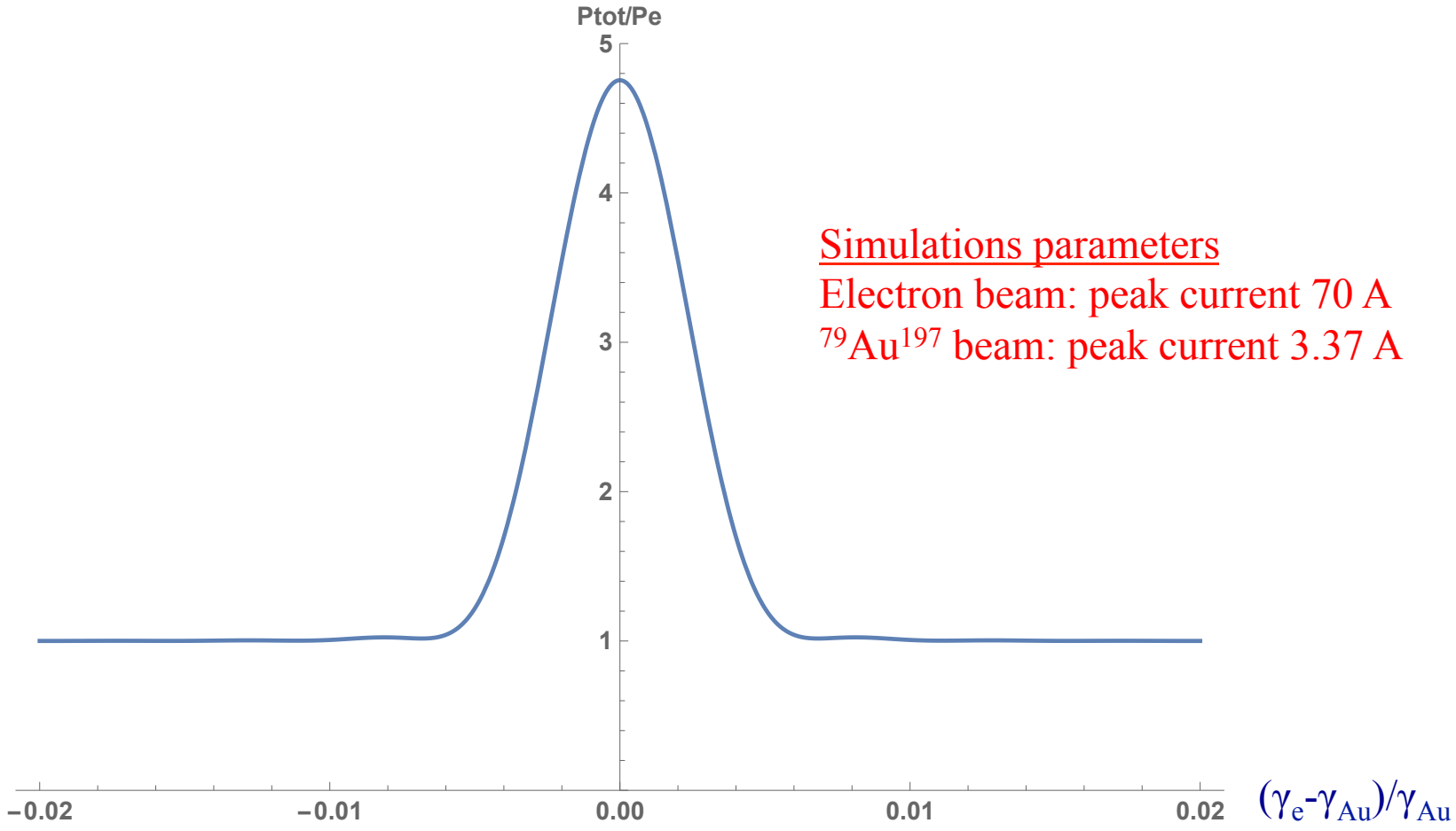
CeC: Diagnostics

- Review the measurement of the small beam energy spread to make sure the needed resolution and ease of use are available at turn-on.
  - YAG screen and GiGi camera resolution is sufficient for measuring the required energy spread
- Review the measurement procedure of the absolute electron and hadron beam energies to make sure all known systematic errors at the 1 part in 1000 level are accounted for.
  - Absolute measurements of the energies are not required. Matching relativistic factors with 3×10^{-4} accuracy should be sufficient for the task in hand. Electron beam energy can be monitored by BPM electronics at the required level in the dog-leg. We expect that RHIC energy is also reproducible with 3×10^{-4} accuracy. This will be verified by our spontaneous radiation measurements (see 2 slides down)
- Specify, measure and understand the various timing jitters among different RF, diagnostic and laser systems and the hadron bunch
  - We specified the requirements on jitter to be less than 100 ps between ion and electron beams and 0.1 degree RF phase and laser pulse stability (at 112 MHz). These parameters are not yet demonstrated, but we expect that LLRF and laser system would meet this requirements.

Electron Beam and FEL Parameters
for CeC PoP experiment

Electron Beam	
RMS Energy Spread	$\leq 1\times10^{-3}$
Normalized Emittance	≤ 5 μm·rad
Peak Current	60-100 A

Matching velocities/relativistic factors
We rely on the increase of the short noise in electron beam induced by ion's in the modulator



Simulations parameters
Electron beam: peak current 70 A
$^{79}Au^{197}$ beam: peak current 3.37 A

Plot shows the power of spontaneous radiation from CeC wigglers as function of the difference of relativistic factors between electrons as ions $(\gamma_e-\gamma_{Au})/\gamma_{Au}$. When velocities are synchronized, ions induced additional short noise in the electron beam and increase the spontaneous emission more than 4-fold.

CeC: e-gun Commissioning and Final System Commissioning Plan

- No recommendations
- You will see progress yourself tomorrow during the tour

Questions?